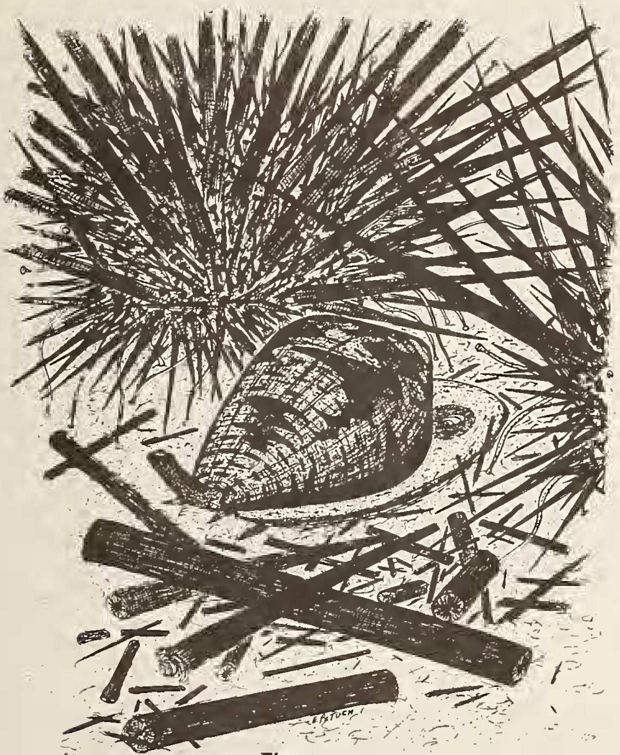

Figure 7

Africonus echinophilus Petuch, spec. nov. in association with the sea urchin *Echinometra* sp.

Holotype: California Academy of Sciences, San Francisco, California, Geology Department Type Collection No. 55454.

Ecology: Like the other species in *Africonus*, *A.* ***echinophilus*** prefers a high energy environment on a rocky substrate. Its diminutive size permits it to wedge into small cracks among rocks or into holes eroded by sea urchins. The foot is unusually large and broad for a cone, giving increased tenacity in a wavy habitat.

Etymology: The name **echinophilus** translates as "sea urchin lover"; from the Greek "philos," loving, and "echinus," in reference to the class Echinoidea, Phylum Echinodermata, the sea urchins.

Discussion: *Africonus* ***echinophilus*** (Figures *1*, *2*, and *3*) is one of the smallest species of cone shells; the average length for twenty-five specimens collected was only 11.5 mm. Its closest living relative is *A. anthonyi* Petuch, 1975, from SaoTiago Island, Cape Verde Islands (Petuch, 1975). The distinctive coloration patterns of the two species, however, make them easily separable. *A. anthonyi* has the unique zigzag "tweed" patterning which *A.* ***echinophilus*** lacks completely.

The local collectors around Dakar, Senegal, have occasionally come across this rare little shell, but have mislabeled it as a juvenile *Lautoconus ventricosus* (Gmelin, 1791) (=*Conus mediterraneus* Hwass, 1792). It shows little resemblance to that species, both in shell morphology and coloration. The body forms of the animals are also very different. *Africonus* ***echinophilus*** could also be confused with juveniles of *Lautoconus grayi* (Reeve, 1844) which is quite common in the Dakar-N'Gor area. The animals, however, when viewed together, differ greatly. *Lautoconus grayi* has a light yellow-brown foot and proboscis, these being heavily covered with black fleckings as is typical of the genus *Lautoconus*. *Africonus* ***echinophilus***, on the other hand, has a very broad foot, colored a brilliant rose-pink, devoid of black fleckings, and has a distinct black proboscis and black dorsal spot.

The habitats of the two species are also different. *Lautoconus grayi*, being of a larger size (40 mm in length), prefers more sheltered areas and can be found in sand under large rocks at low tide. *Africonus* ***echinophilus*** is found only in the surge zone on the extreme seaward edge of the rock reefs. It is the only cone shell known to live in close association with colonies of sea urchins.

The recent increased commercial fishing in the deep waters surrounding the Cape Verde region has resulted in the discovery of many new and rare gastropods. Such interesting forms as *Marginella desjardini* Marche-Marchad, 1957, *M. punctulata* Petit, 1841, and a number of species as yet undescribed in the genera *Epitonium*, *Murex*, *Cypraea*, and *Coralliophila*, have been regularly encountered in fishing nets. This deep water faunal assemblage seems to be of a highly endemic nature, showing few relationships with the deep water faunas to the north or south.

While sorting through collections of shells taken from the lower continental shelf by scallop and shrimp boats, three specimens of a beautiful violet-colored new cone shell were found. They resembled none of the known species found along the West African coast. The following taxon is proposed:

Leptoconus Swainson, 1840

Leptoconus ***gernanti*** Petuch, spec. nov.

(Figures *4* to *6*)

Description: Shell elongate, polished, composed of 8 whorls. Shoulder sharp, wide, and carinated. Spire elevated, weakly scalariform, lacking spiral sutures, with a deep channel and smooth spire whorls. Protoconch sharp and mamillate. Body whorl miscrosculpture made up of distinct wavy vertical lines running the entire length of the shell, giving it a silky appearance. Columella with 8 weak sulci. Color pale lilac encircled with two darker violet bands; one extending from the shoulder to midline, the other from below midline to the spiral sulci of the columellar area. This violet color is in turn overlaid with intermittent light tan flammules that extend the entire body length. Spire coloration pale violet with dark brown crescent-shaped flammules. Aperture pale violet, becoming more intense in the interior. Operculum fairly large, elongate and black. Periostracum thin, dark brown, with wavy vertical lines correlating to the shell microsculpture.

Animal: The entire body is uniformly colored a brilliant orange-red.

Dimensions of Holotype: length 40 mm, width 23 mm.

Type Locality: The holotype and 2 other specimens were dredged by fishing boats from approximately 60 m of water, 15 km NW of M'Bour, Petit Côte, Senegal, West Africa (14°41'N; 17°30'W).

Occurrence: *Leptoconus gernanti* appears to be restricted to the narrow continental shelf region surrounding Cape Verde.

Holotype: California Academy of Sciences, San Francisco, California, Geology Department Type Collection No. 55453.

Ecology: This species prefers a sand substrate at depths ranging from 50 to 100 m. Other gastropods associated with it were *Bursa marginata* (Gmelin, 1791); *Cancellaria cancellata* (Linnaeus, 1758); *Genota mitraeformis* (Wood, 1828); *Genota vafra* Sykes, 1905; *Crassispira carbonaria* (Reeve, 1843); *Leptoconus genuanus* (Linnaeus, 1758); *Polinices grossularia* Marche-Marchad, 1957; and many others.

Discussion: *Leptoconus gernanti* (Figures *4, 5, 6*) is one of the most striking and distinct of all the West African cones. The only other species it could possibly be confused with is *L. ambiguus* (Reeve, 1844). That species, however, lacks the distinct wavy microsculpture of *L. gernanti,* has a much less elevated spire, and more narrow shoulder region. *Leptoconus gernanti* is always an intense violet color, while *L. ambiguus* is an off-white color, occasionally streaked with brown or yellow. *Leptoconus ambiguus* also lacks the sharp, mamillate protoconch of *L. gernanti,* and has a series of 3 deeply incised spiral grooves on the spire which the latter species never shows. The animals of both of these species are very different. The orange-red animal of *L. gernanti* could never be confused with the yellow-brown colored *L. ambiguus.*

The ecologies of both *Leptoconus ambiguus* and *L. gernanti* are quite different: *L. ambiguus* prefers rocky intertidal areas, and it can be collected quite commonly at low tide in tide pools around Cape Verde; *L. gernanti,* on the other hand, lives on a sandy substrate in deep water offshore where it is virtually inaccessible except by dredging.

What is most interesting about this new species is its affinities to several of the Western Atlantic cone shells in the genus *Leptoconus.* Such species as *L. villepini* (Fischer and Bernardi, 1857), *L. bermudensis* (Clench, 1942), *L. caribbaeus* (Clench, 1942), and pale color forms of *L. juliae* (Clench, 1942) all show a close relationship to *L. gernanti.* This is one of the few West African cones that exhibits any faunistic ties with the Caribbean and tropical West Atlantic. More intensive dredging in the deep water regions around Cape Verde will most probably bring to light many new lower continental shelf cone shells. This species is named in honor of Dr. Robert E. Gernant, Paleontologist and Malacologist, Department of Geological Sciences, University of Wisconsin–Milwaukee, Milwaukee, Wisconsin.

The discovery of *Africonus echinophilus* and *Leptoconus gernanti* represents a significant contribution to our knowledge of the Eastern Atlantic toxiglossate fauna. The bizarre ecology of *A. echinophilus* lends insight into the wide variety of niches that are open to occupation by cone shells. *Leptoconus gernanti* demonstrates the possibility of amphi-Atlantic distributions of several prominent conid genera and species complexes.

ACKNOWLEDGMENTS

I would like to thank Mr. John Alley, Photographic Services, University of Wisconsin–Milwaukee, for the fine quality photographs used in this paper, and Ms. Patricia Abram, for typing of the manuscript and critical review.

Literature Cited

Clench, William James
1942. The genus *Conus* in the western Atlantic. Johnsonia 1 (6): 1-40; 15 plts. Harvard Univ. Cambridge (5 December 1942)

Petuch, Edward J.
1975. A review of the small Mauretanian cone shells with descriptions of a new genus and a new species (Gastropoda : Conidae). The Veliger 17 (3): 262-263; 1 plt. (1 January 1975)

Shepard, Francis P.
1973. Submarine Geology. 3rd ed., 517 pp.; 267 figs. Harper & Row, Inc. New York

Explanation of Figures *1* to *6*

Africonus echinophilus Petuch, spec. nov.

Figure *1*: Dorsal aspect of holotype; length 11 mm; width 7 mm
Figure *2*: Ventral aspect of holotype
Figure *3*: Another specimen

Leptoconus gernanti Petuch, spec. nov.

Figure *4*: Dorsal aspect of holotype; length 40 mm; width 23 mm
Figure *5*: Ventral aspect of holotype
Figure *6*: Another specimen

Figure *1*

Figure *2*

Figure *3*

Figure *4*

Figure *5*

Figure *6*

Studies on the *Mytilus edulis* Community in Alamitos Bay, California.

V. The Effects of Heavy Metals on Byssal Thread Production

BY

J. MICHAEL MARTIN [1], FRED M. PILTZ [2] AND DONALD J. REISH [1]

(6 Text figures)

INTRODUCTION

IN AN EARLIER STUDY dealing with the physiological ecology of *Mytilus edulis* Linnaeus, 1758, a direct relationship was found to exist between the number of byssal threads produced per unit time and the concentration of dissolved oxygen or salinity of the water under laboratory conditions (REISH & AYERS, 1969). With these data it was possible to ascertain a sublethal level at which either environmental factor would affect byssal thread production. GLAUS (1968) found that small mussels produced more threads than larger ones at normal salinity and the number of threads produced increased with an increase in temperature up to 28° C. VAN WINKLE (1970) found that mussels died when temperature exceeded 26° C. Mussels produced a greater number of threads at night than during the day. Byssal thread number also increased when mussels were placed together in the same container rather than in separate containers, (MARTELLA, 1974).

Since the discovery that mercury caused Minimiata disease in Japan, there has been a considerable interest in the effect of various metals on marine organisms. Because *Mytilus edulis* and related species are widely distributed, these pelecypods have been utilized in studies related to environmental conditions. Studies with *M. edulis* have involved the effects of various metals on survival (WISELY & BLICK, 1967; EISLER, 1971; SCOTT & MAJOR, 1972), development (COURTRIGHT *et al.*, 1971), the suppression of gill ciliary activity (BROWN & NEWELL, 1972), metabolism (HOBDEN, 1969; BROWN & NEWELL, 1972; SCOTT & MAJOR, 1972) and residual concentrations in both shell and soft parts (MARKS, 1938; PENTREATH, 1973; SCHULZ-BALDES, 1974). These studies are difficult to correlate because of the different parameters measured, the different types and concentrations of heavy metals used, and the different lengths of experimental period. Survival of *M. edulis* or other pelecypods has been stressed in most studies dealing with the effects of heavy metals as pollutants. The results of such studies are generally given as a LC_{50}, that is the concentration at which 50% of the test organisms are killed over a period of time, typically 96 hours. Water quality standards are then set for the discharge of the particular pollutant into the environment using these data, and other data. Unfortunately, these data give no real indication of the concentration which will cause a sublethal effect of a pollutant. Sublethal pollution is herein considered as a cause of long-term biological effects on an organism resulting from some man-made change in the environment. The effect may not cause the direct death of the organism, but the change in the environment may cause some alteration of a biological process(es) which would lead to the inability of the organism or its offspring to function normally, and may ultimately lead to its death. Since byssal threads are secreted by the mussel for attachment to the substrate, this secretion represents an active metabolic activity of the organism. The number of byssal threads produced over a period of time may then be a measure indicative of the degree of sublethal pollution. The purpose of this paper is to determine the number of byssal threads produced in varying concentrations of 6 metals over a 7 day period and to correlate these data to the concentration of these metals in discharges from domestic sewers. The correlation will then permit an evalu-

---

[1] Department of Biology, California State University, Long Beach, Long Beach, California 90840

[2] Department of Biological Sciences, University of Southern California, Los Angeles, California 90007

ation as to whether or not the concentrations of these heavy metals present in domestic sewage discharges represent a potential danger to these organisms.

MATERIALS AND METHODS

Specimens of *Mytilus edulis* were collected from boat floats in Alamitos Bay marina. The surface of the shell was cleaned of all fouling organisms and the emergent byssal threads were cut with scissors. The specimens were then kept in 17° C sea water for two days. Prior to use all newly formed emergent byssal threads were again cut. One specimen was placed in a 500 ml erlenmeyer flask with 100 ml of sea water and varying concentrations of one of six different heavy metals. Ten specimens were used for each concentration plus 10 for a sea water control series and 10 for citrate control when required. The animals were not fed during the course of the experiment.

The chemicals used in this experiment were of reagent grade and included the following: cadmium as $CdCl_2$, chromium as CrO_3, copper as CuSO, lead as Pb (CH_3 $COO_2)_2$, mercury as $HgCl_2$, and zinc as $ZnSO_4$. Preliminary experiments were conducted with few organisms over a wide concentration range in order to define the final experimental limits. The second series of experiments was conducted for a 7 day period. At the conclusion of these experiments the number of byssal threads produced by each individual was counted.

The concentrations of the various heavy metals in these experiments included the following: cadmium, 0.1, 0.5, 1.0, 5.0, and 25 mg/l; chromium, 1.0, 2.0, 3.0, 4.0, 5.0, 15.0, 30.0, and 60.0 mg/l; copper 0.05, 0.1, 0.2, 0.3, 0.4, 0.5 and 1.0 mg/l; lead, 1.0, 5.0, 10.0, 15.0, 20.0, and 25 mg/l; mercury, 0.01, 0.05, 0.1, 0.5, 1.0, and 5.0 mg/l; zinc, 0.1, 0.5, 1.0, 2.0, 3.0, 4.0, and 5.0 mg/l. Sodium citrate was used as a chelating agent for copper, lead and zinc to prevent precipitation of the metal. Because this added a new variable, a sodium citrate control was run in all chelated metal solutions at the concentration of sodium citrate used to bind a 100 mg/l metal solution. The lead solution was acidified with 0.1 N HCL to get all lead into a 100 mg/l stock solution. Low concentrations of lead sodium citrate were adjusted to normal sea water pH levels with O.1 N NaOH.

RESULTS

The data for the effects of various heavy metals on survival and byssal thread production are summarized in Figures 1–6 and Table 1. Figures 1–6 present the mean number of byssal threads produced at each metal concentration for the 7 day experimental period. A narrow range can be seen from each of the figures where the mean number of byssal threads produced decreases markedly with a slight increase in the concentration of the metal. Table 1 summarizes this information according to the lethal concentration of metal which caused a 50% reduction in survival, the LC$_{50}$; the effective concentration which caused a 50% reduction in the mean number of byssal threads produced as compared with the control of that metal, the EC$_{50}$; the waste discharge requirements for the State of California; and the trace metal concentration of the discharge of two Los Angeles outfall systems (Anon., 1972; 1973).

Mercury was the most toxic of the six metals tested, followed by copper, cadmium, zinc, lead, and chromium. In all metals tested, except zinc, the reduction in the mean byssal thread production was followed by a reduction of

Table 1

Comparisons of the LC$_{50}$ and EC$_{50}$ of Survival and Byssal Thread Production in *Mytilus edulis* to Water Quality Standards and Concentration of Metals in Waste Discharges

Metal	LC$_{50}$	EC$_{50}$	State of California Waste Discharge Requirements not to be exceeded more than:		Trace Metal Concentrations in Waste Discharges in two Los Angeles Outfall Systems
	(mg/l)	(mg/l)	50% of time (mg/l)	10% of time (mg/l)	(mg/l)
Cadmium	2.5	0.5	0.02	0.03	0.03 - 0.05
Chromium	5.0	3.9	0.005	0.01	—
Copper	0.3	0.25	0.2	0.3	0.23 - 0.52
Lead	>25.0[1]	2.5	0.1	0.2	0.06 - 0.16
Mercury	0.15	0.2	0.001	0.002	—
Zinc	>5.0[1]	1.8	0.3	0.5	0.46 - 2.4

[1] Survival values greater than the highest concentration of metal used.